

DESIGN OPTIMIZATION FOR COST AND QUALITY:
THE ROBUST DESIGN APPROACH

by

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Designing reliable, low cost and operable space systems has become the key to future space operations. Designing high quality space systems at low cost is an economic and technological challenge to the designer. A systematic and efficient way to meet this challenge is a new method of design optimization for performance, quality and cost, called, Robust Design. Robust Design is Dr. Genichi Taguchi's approach for design optimization. It consists of:

- Making system performance insensitive to material and subsystem variation, thus allowing the use of less costly materials and components,
- Making designs less sensitive to the variation in the operating environment, thus improving reliability and reducing operating costs,
- Using a new structured development process so that engineering time is used most productively.

The objective in Robust Design is to select the best combination of controllable design parameters so that the system is most robust to uncontrollable noise factors. The robust design methodology uses a mathematical tool called an orthogonal array, from design of experiments theory, to study a large number of decision variables with a significantly small number of experiments. Robust design also uses a statistical measure of performance, called a signal-to-noise ratio, from electrical control theory, to evaluate the level of performance and the effect of noise factors.

The purpose of this research is to investigate the Robust Design methodology for improving quality and cost, demonstrate its application by the use of an example, and suggest its use as an integral part of space system design process.

The three steps of the design process are, system design, parameter design, and tolerance design. System design involves innovation and technical knowledge of the engineer to develop a design architecture that meets the functional requirements. After the system architecture is decided on, the next step is to select the optimum levels for the controllable design parameters such that the system is functional, exhibits a high level of performance under a wide range of conditions, and is robust to noise factors. Parameter design has the greatest impact on cost and quality. Studying the design variables one at a time or by trial and error is the common approach to design optimization. This leads to either a very long and expensive time span for completing the design or a premature termination of the design process such that the product design is far from optimal. As an alternative, Robust Design significantly reduces the number of experimental configurations to be studied. Thus, research and development costs are reduced due to the improved efficiency of generating information needed to design systems so that they are insensitive to operating conditions, production variation and deterioration of parts. As a result, production and operations costs are also greatly reduced.

The third step, tolerance design, is only required if robust design can not produce the required performance without costly special components or high process accuracy. It involves tightening of tolerances on parameters where their variability could have a large negative effect on the final system. Typically tightening tolerances leads to higher cost.

Robust Design methodology was applied to a Heat Exchanger Design optimization problem. The objective was to determine the optimum combination of controllable design parameters to minimize cost considering the uncertainty due to noise factors. The steps in the Robust Design study consisted of:

1. Identify the main function,
2. Identify the noise factors and testing conditions,
3. Identify the quality characteristic to be observed and the objective function to be optimized,
4. Identify the control factors and their alternative levels,
5. Design the matrix experiment and define the data analysis procedure,
6. Conduct the matrix experiment,
7. Analyze the data, determine optimum levels for the control factors,
8. Predict the performance under these conditions.

The results of the study indicate that Robust design methodology can truly aid design engineers in designing for low cost and high quality. Principal benefits are; time and resource savings, handling of nonlinearities and interactions, quantitative measures of sensitivity of optimum results and, quantitative recommendations to which design parameters should be changed to achieve minimum cost, high quality solutions.